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Network Asymmetry and GNSS

Delivering Precise Robust Synchronization

George Zampetti

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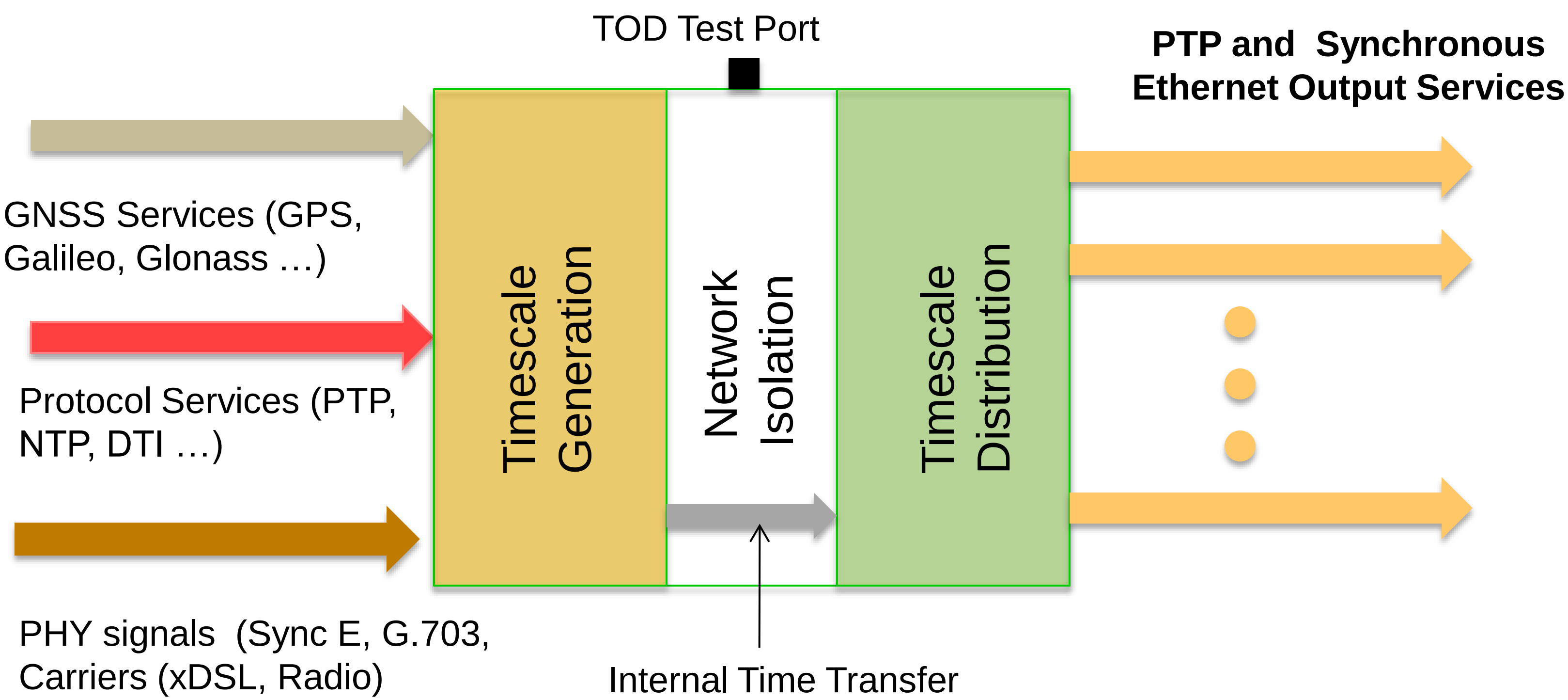
Gateway Clock Background
(Fusion of Inputs)

Gateway Clock with GNSS

PTP with GNSS based Automatic
Path Delay Compensation

Summary

Gateway Clock Functional View



Gateway Clock- Multiple Control Planes

- A gateway clock generates traceable time and frequency outputs :
    - Source for Time Control can be different than Frequency Control
    - The frequency control plane stabilize the local oscillator to support enhanced time control.
    - Frequency and Time control operate simultaneously
    - Traceability Control mitigates path asymmetry
- Practical examples of network inputs are shown. Of course basic operation with single input is an option.

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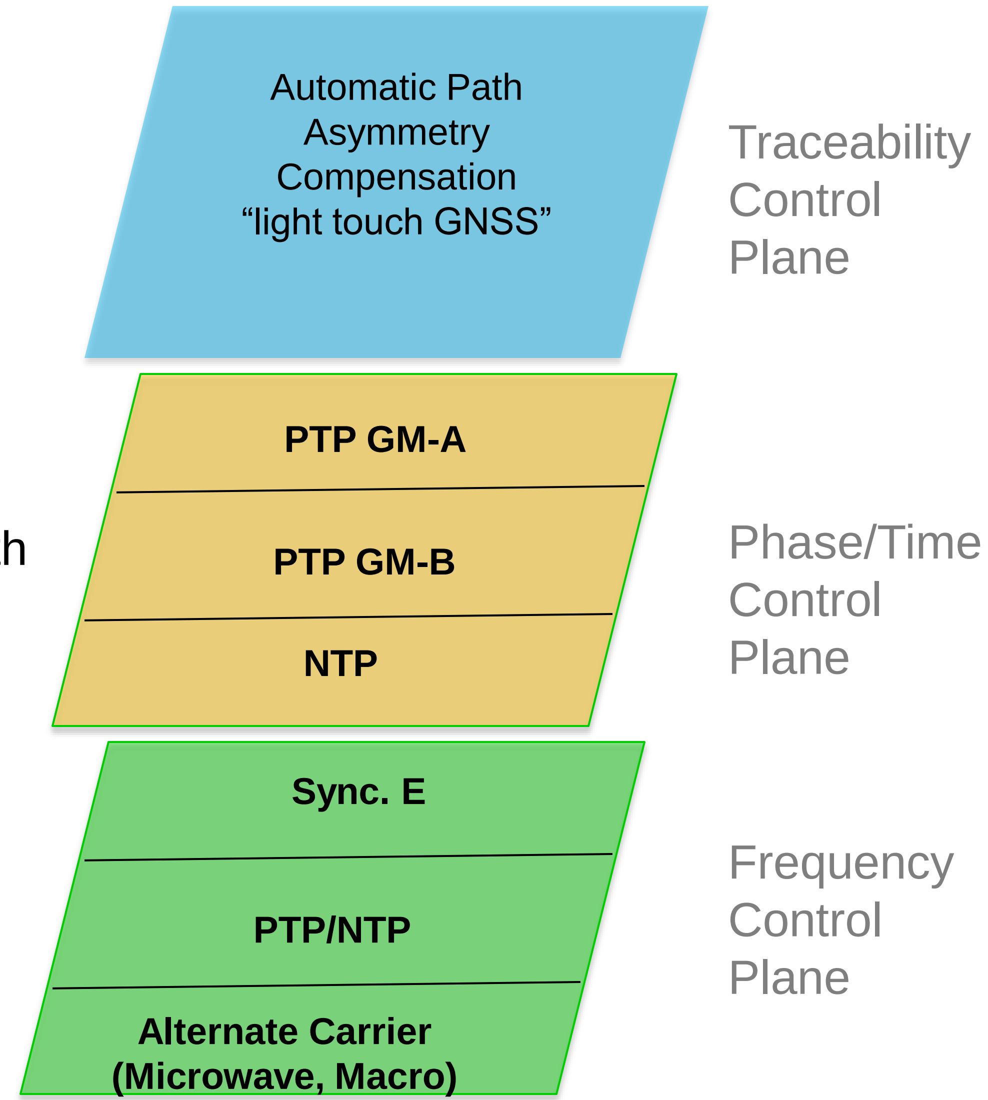

Why Automatic Path Asymmetry Compensation ?

The fundamental issue of asymmetry is captured in both the original 1588v1 standard (2002) as well as the subsequent release 1588v2 in 2008.

Excerpts from IEEE 1588-2002

The following assumptions must be met to achieve optimal clock synchronization performance: (6.1.3)

— Network delay between master and slave on a subnet must be symmetric (see 7.8.1.2).

This computation assumes that the path lengths are identical in the two directions. If additional knowledge is available concerning any possible path asymmetry, this computation shall be corrected so that the value of (one_way_delay) more accurately represents the time of propagation of a Sync message from the master to the slave clock. (7.8.1.2)

- Section 6.2 Principle assumptions about the network and implementation recommendations

Like all message-based time transfer protocols, PTP time accuracy is degraded by asymmetry in the paths taken by event messages; see 7.4.2. Specifically the time offset error is 1/2 of the asymmetry. (6.2)

Asymmetry is not detectable by PTP; however, if known, PTP corrects for asymmetry. (6.2)

Asymmetry can be introduced in the physical layer, e.g., via transmission media asymmetry, by bridges and routers, and in large systems by the forward and reverse paths traversed by event messages taking different routes through the network. Systems should be configured and components selected to minimize these effects guided by the required timing accuracy. In single subnet systems with distances of a few meters, asymmetry is not usually a concern for time accuracies above a few 10s of ns. (6.2)

Why Automatic Path Asymmetry Compensation ?

Excerpts from IEEE 1588-2008

Excerpt from IEEE 1588-2008 Section 6.6.3 Synchronizing ordinary and boundary clocks

The computation of offset and propagation time assumes that the master-to-slave and slave-to-master propagation times are equal. Any asymmetry in propagation time introduces an error in the computed value of the clock offset. The computed mean propagation time differs from the actual propagation times due to the asymmetry. (6.6.3)

Asymmetry effects are not limited to delay mechanisms only on the switches and routers asymmetry will be introduced in the physical layer.

Any asymmetry in the propagation times t-ms and t-sm introduces an error into the computed value of the link delay. (6.6.4)

The overarching issue of asymmetry is the focus of the next section. It defines a correction term (delay_asymmetry) with the conclusion that measuring this term is beyond the scope of the IEEE 1588 standard.

Messages from master to slave and slave to master shall traverse the same network path in any system containing two-step clocks on such paths. Messages from requestor to responder and from responder to requestor shall traverse the same network path in any system containing two-step clocks on such paths. They should traverse the same path in all systems to minimize asymmetry.

The measurement of delay_asymmetry is out of scope of this standard. (7.4.2)

Limits of asymmetry error

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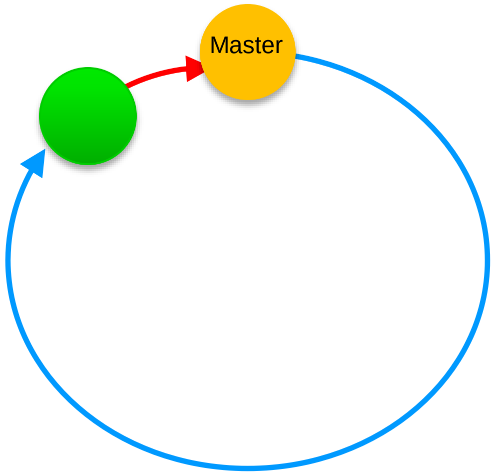
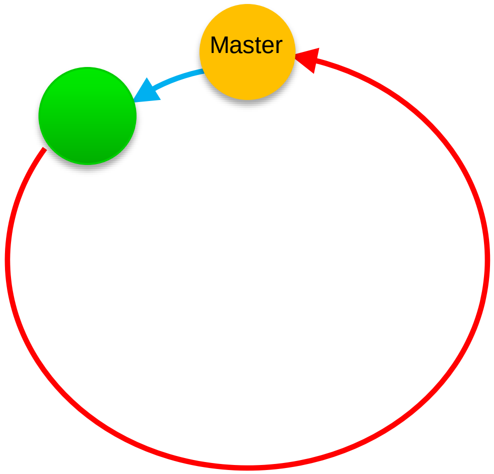
Case A: Long Forward Path and Short Reverse Path. Under Estimate Forward Delay using (Round-Trip-Delay/2). Worse Case Slave Time behind Master by (RTD/2)



Case B : Short Forward Path and Long Reverse Path. Over Estimate Forward Delay using (Round-Trip-Delay/2). Worse Case Slave Time ahead Master by (RTD/2)



Note: Asymmetry Error directly proportional to Round Trip Delay
Delivery Time Traceability limited by Round Trip Delay

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Gateway Clock Description

Gateway Clock with GNSS

PTP with GNSS based Automatic Path Delay Compensation

Summary

GNSS Automatic Antenna Cable Delay Calibration

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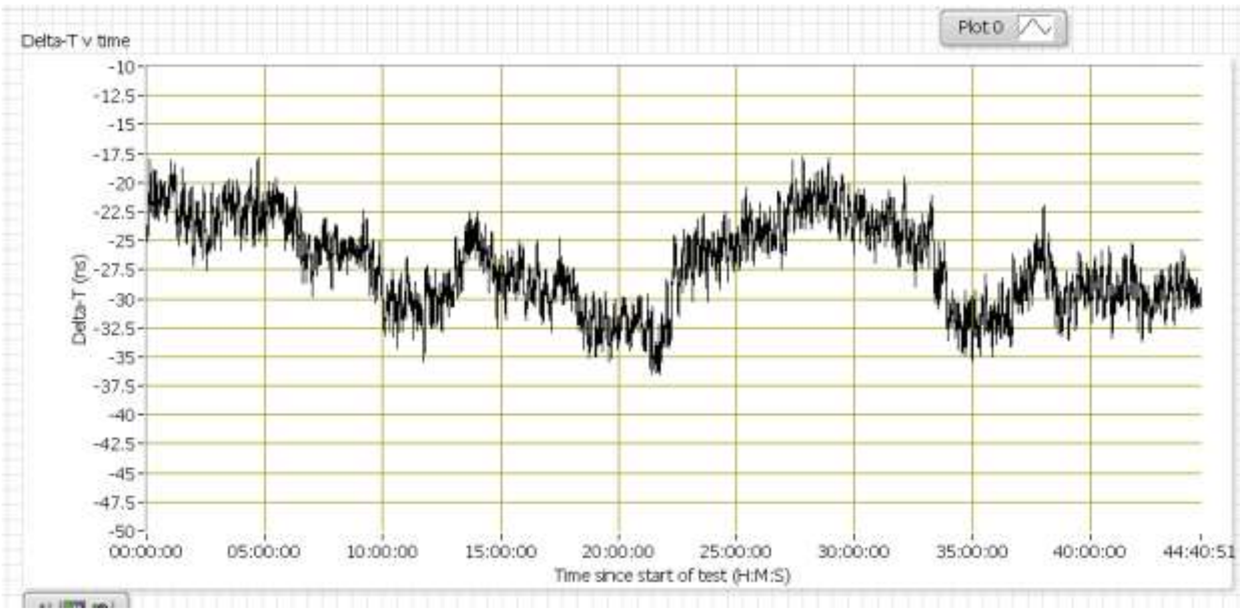
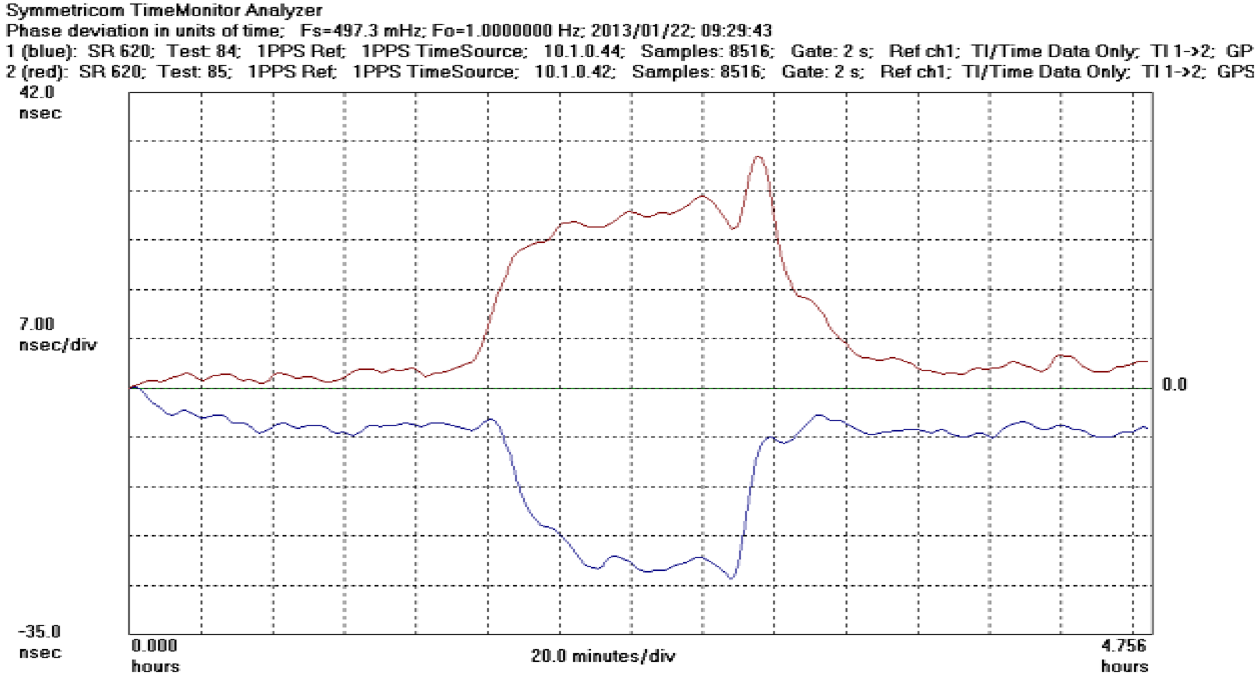


Cable Delay Bias Mitigation Test Results (200ft and 700ft cable swap)

GNSS (GPS L1) Antenna Group Delay Bias Effects



Bias Skew when interchanging GPS Antenna

“Rooftop” GPS with and Two 10 MHz Physical References Simultaneously

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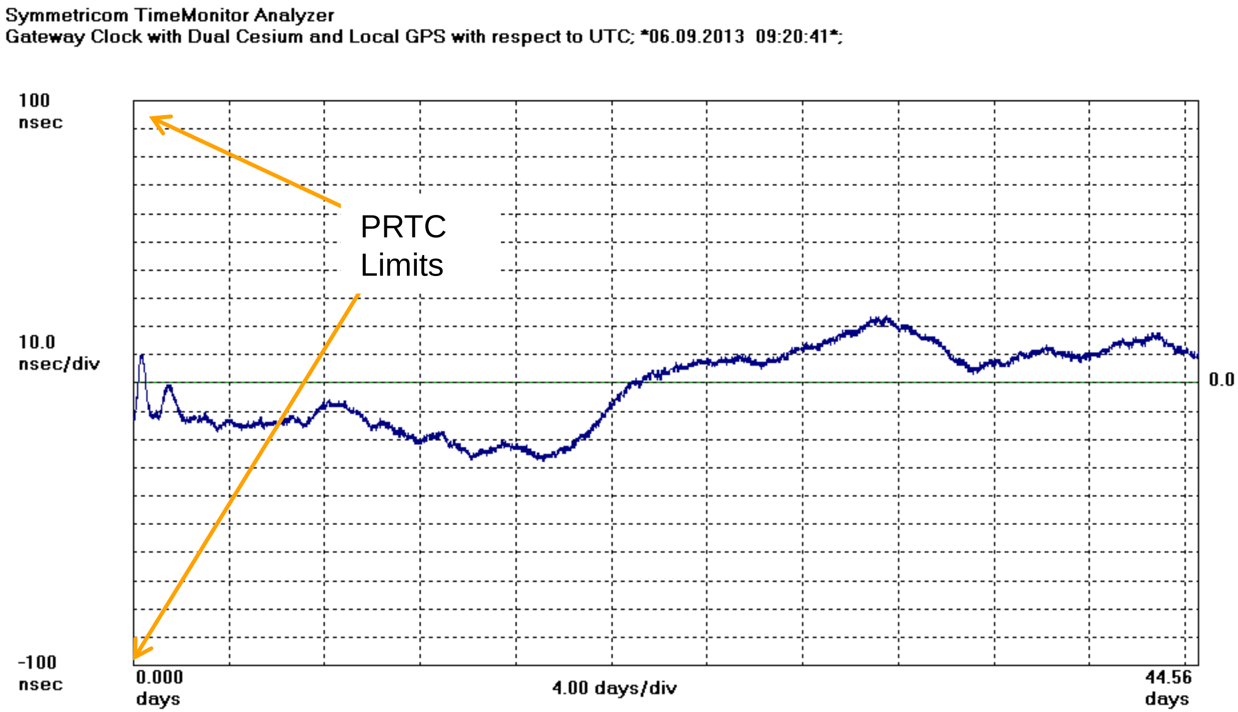
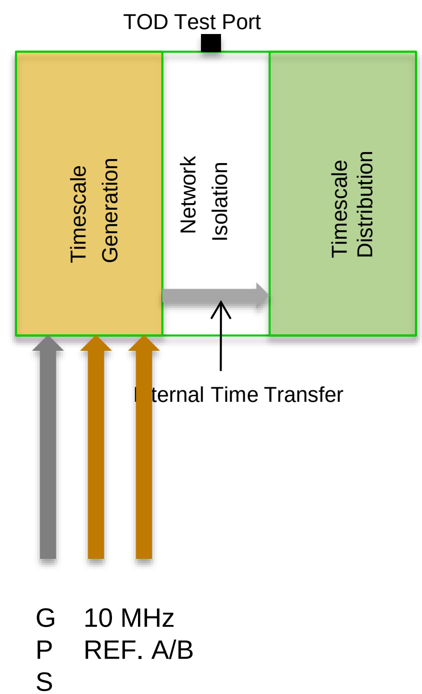
Gateway Clock Operating for 44 days in 3rd party test with:

1) Rooftop L1 only GPS only with automatic cable compensation

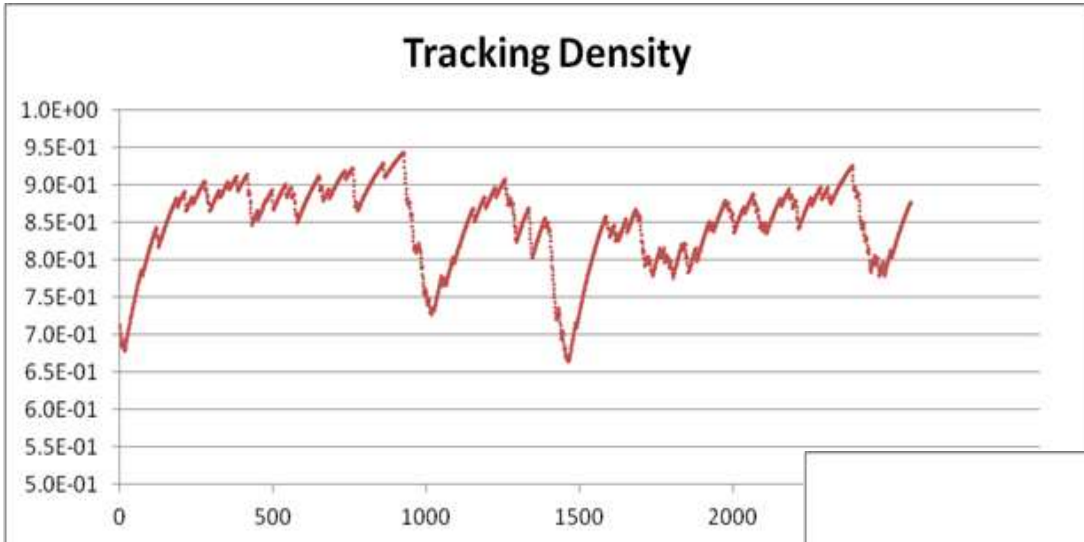
2) Two 10 MHz references from local cesium references



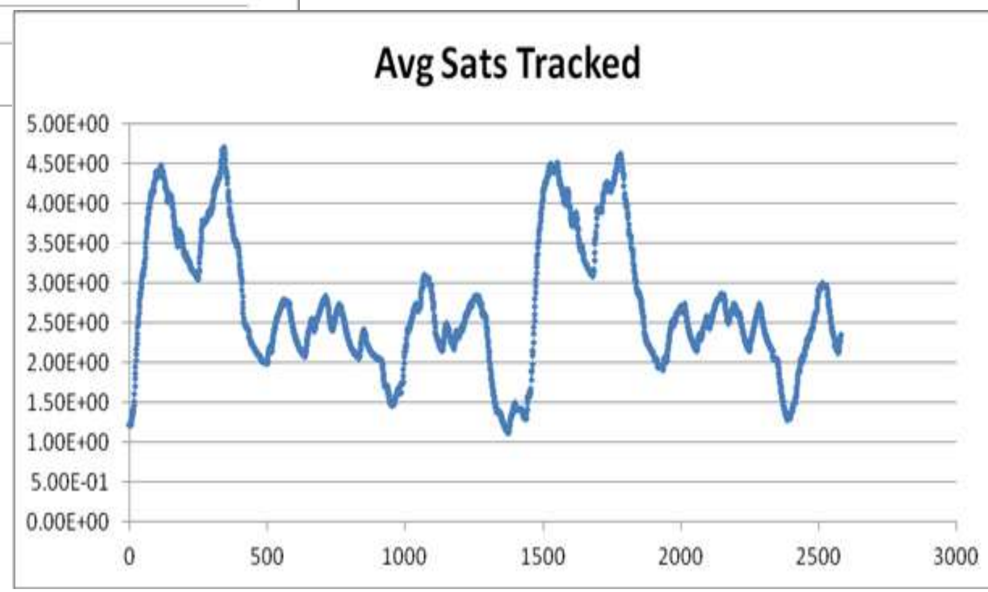
1 PPS Time Error with respect to UTC



“Light Touch GPS” Key Operating Metrics (no requirement to install antenna on roof)



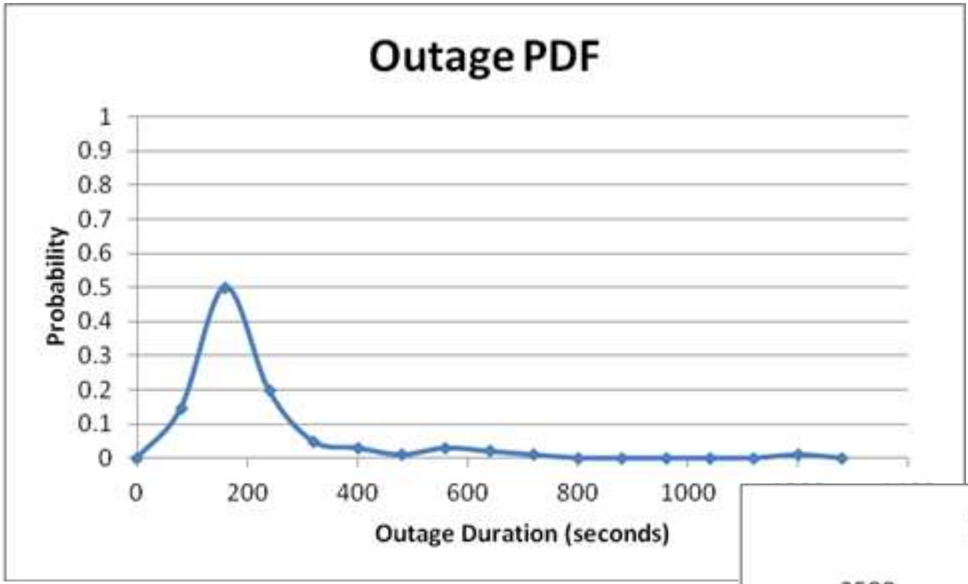
Tracking Density:
Rolling average percentage of one second updates with acceptable GPS operational statistics



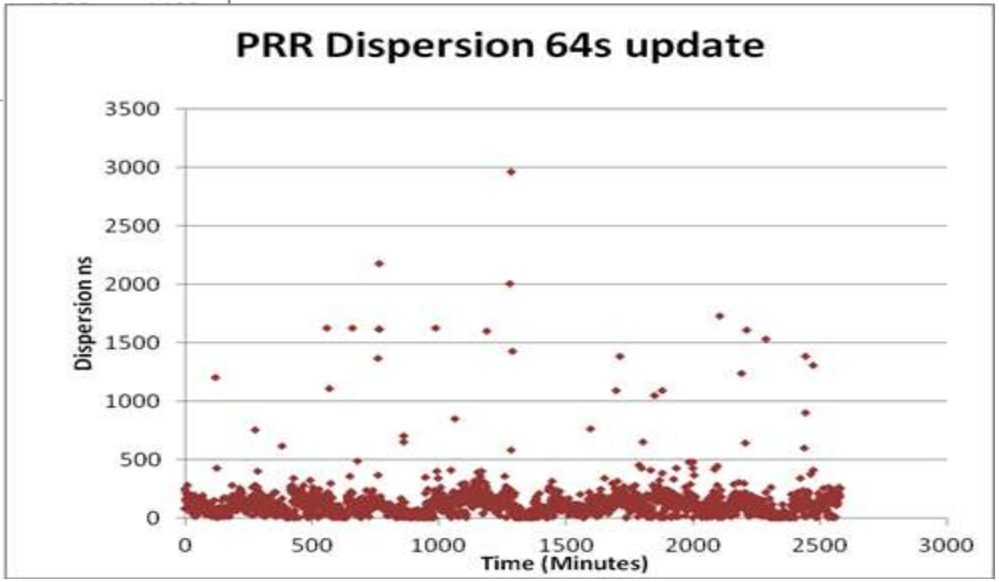
Average Sats Tracked:
Rolling average number useful satellites tracked

First Floor Symmetricom San Jose 5 feet inside Exterior Wall

“Light Touch GPS” Key Operating Metrics



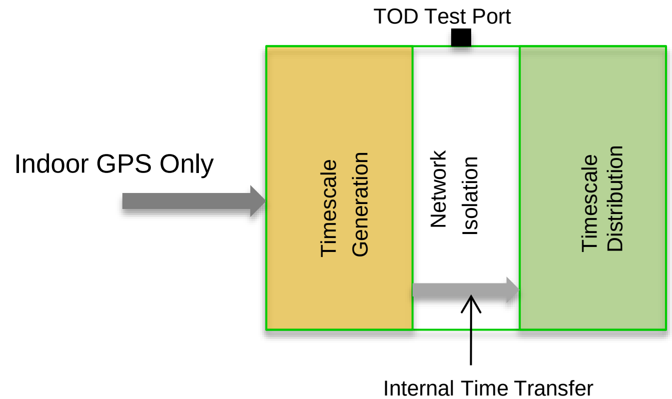
Outage PDF:
The probability distribution function showing the duration of an outage event in the operation environment



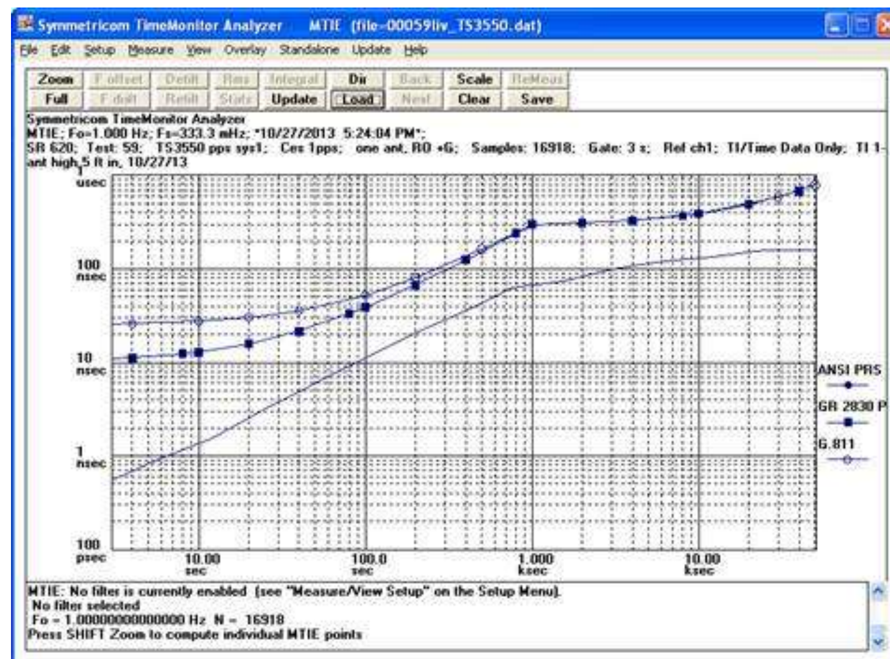
Pseudo Range Residual Dispersion:
With Receiver operation in fixed position mode with an external traceable frequency reference the dispersion is the absolute residual time error of the current time/position state.

First Floor Symmetricom San Jose 5 feet inside Exterior Wall

“Light Touch” GPS Indoor Operation Results



Light Touch GNSS Algorithm dynamically weights time/frequency state estimates to achieve robust performance even in degraded reception environment



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Gateway Clock Description

PTP with GNSS based Automatic Path Delay Compensation

Summary

Using GPS/GNSS to Learn PTP Asymmetries

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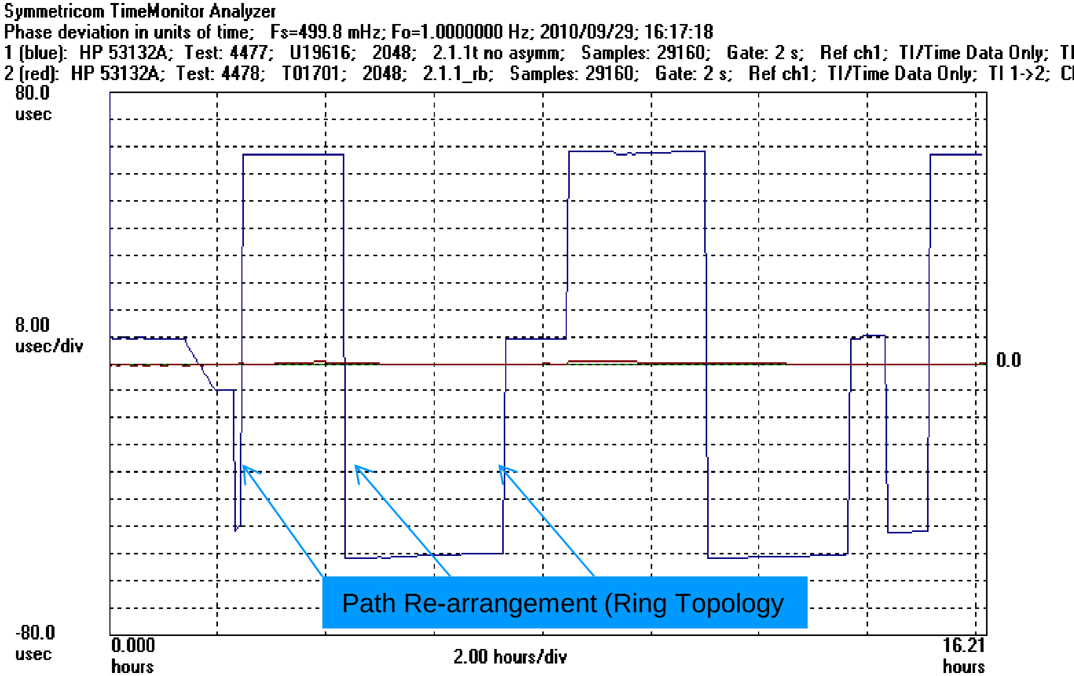
- **Asymmetry Correction Algorithm supplies external correction factor defined in 1588 standard.**
- **Algorithm learns asymmetries to prevent in-accurate time output**
- **Traceability Control Plane allows for intermittent poor reception operation including jamming**

("light touch GNSS")



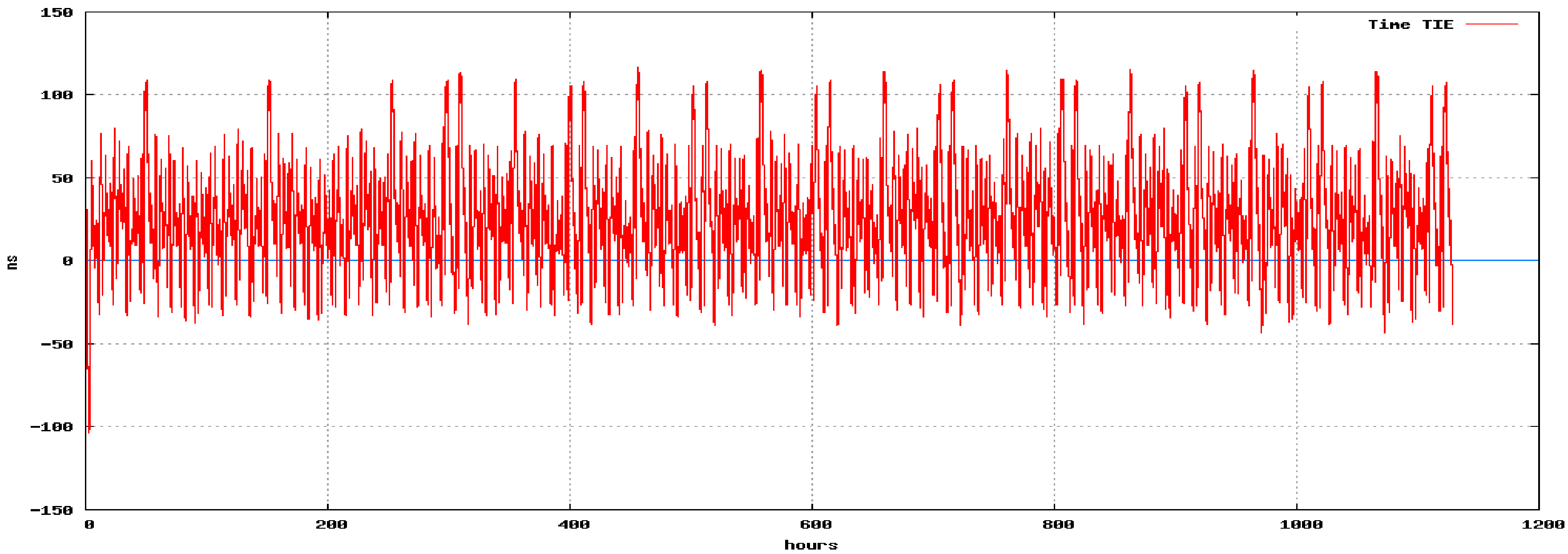
Path Signature			Asymmetry Bias (ns)
Round Trip Delay	Observed Bias	Secondary Path Parameters	
Path Signature A			AAA.A
Path Signature B			BBB.B
Path Signature C			CCC.C

Performance on Customer Network test environment:

BLUE: PPS Performance without Asymmetry correction.

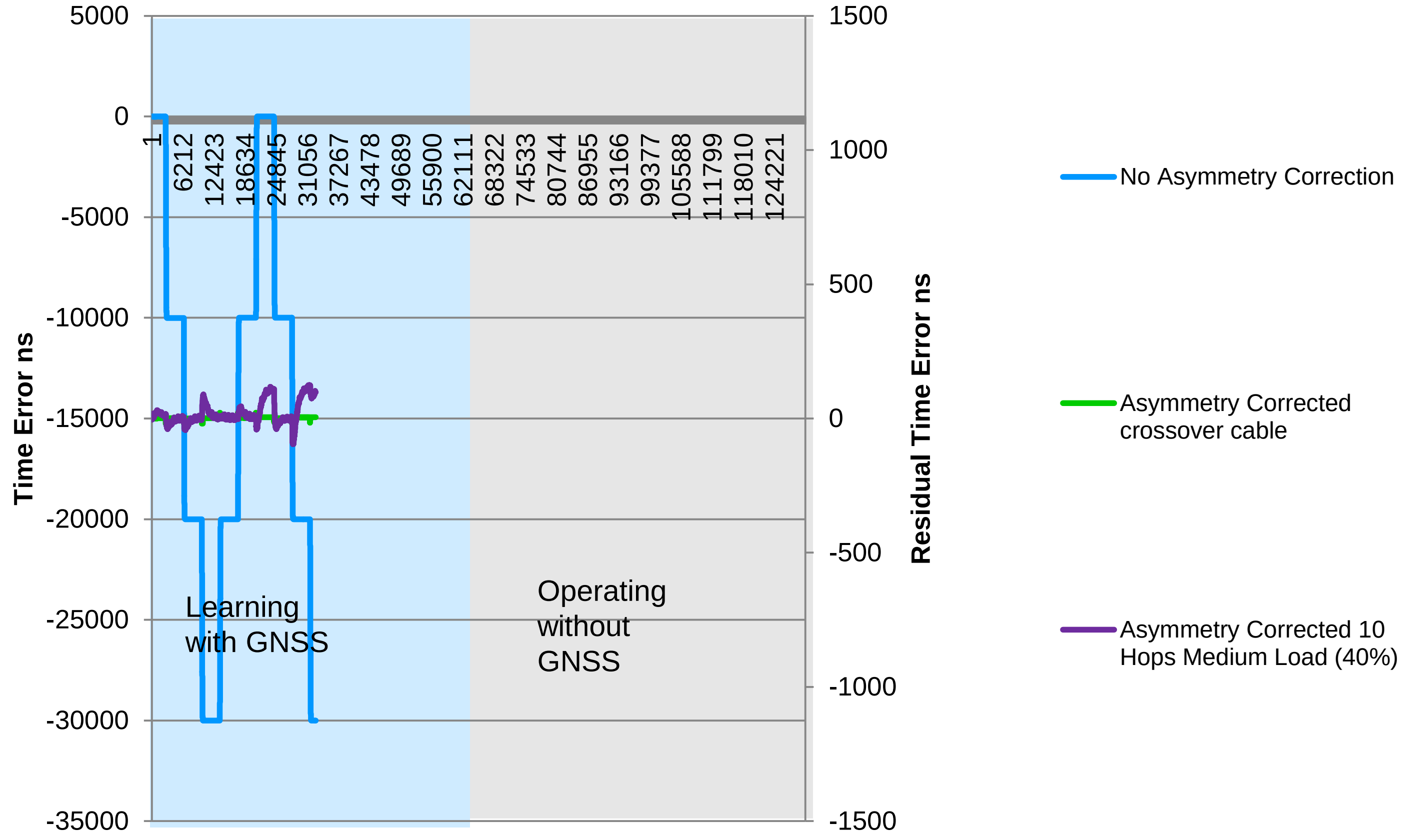
RED: PPS Performance with Asymmetry correction.

Automatic Path Delay Compensation Long Term (45 days)



- Performance based on playback of Customer Network captured packet delay variation including rearrangement transients.
- PTP over Ethernet over SDH (2 rings Ring 1 16 nodes , Ring 2 4 nodes)
- 90 path rearrangement events during test.
- Accuracy better than125ns after warm up.

Automatic Path Delay Compensation Learning Behavior



The Bottom Line …

- Automatic Network Asymmetry correction can be accomplished with "Light Touch GNSS" without the need for rooftop installation.
- GNSS option provides operators required flexibility to provide needed timing services at the edge as PTP matures by allowing alternative frequency sources (Sync E, Macro Sniff).
- GNSS operation can be effectively managed with the use of GNSS metrics

Thank You

George Zampetti
gzampetti@symmetricom.com

Symmetricom, Inc.
2300 Orchard Parkway
San Jose, CA 95131-1017
Tel: +1 408-428-7907
Fax: +1 408-428-6960

www.symmetricom.com